

Lewis River Case Study Final Report

A decision-support tool for assessing watershed-scale habitat
recovery strategies for ESA-listed salmonids

<h2>Appendix J: FishEye</h2>

May 2007

Introduction

The distribution of salmonids on the landscape is influenced by physical habitat variability and the distribution of anthropogenic development. Habitat quality natural varies with the physical and biological landscape. Migration barriers, restoration activities and natural disturbances can modify the extent of and quality of migration, spawning, or rearing habitat. In the context of watershed restoration and fisheries management, it is useful to differentiate natural and anthropogenic-derived variation in hydrology, sediment, and riparian habitat over entire watersheds.

The natural physical, biological, and biochemical conditions of a stream that support migration, spawning, or rearing of salmonids can be described as the natural, or intrinsic potential of a stream (Burnett et al 2003a; Burnett et al 2003b). Intrinsic potential of streams incorporates features that are driven predominantly by general watershed characteristics that vary over the landscape, such as stream gradient, channel form, channel size, and flow regime (Burnett et al 2003a, Montgomery et al. 1999). These characteristics are driven by geology, geomorphology, and topographic variation, which can be predicted using spatial and hydrological modeling.

The purpose of the FishEye model is to describe the intrinsic potential and modified anthropogenic potential of each reach in the watershed with respect to channel width, gradient, and hydrological regime, and to identify reaches whose current potential is limited by either sediment deposition and scour or poor riparian conditions, either intrinsically or as a result of anthropogenic influences. It is a simple assessment tool that provides a reach-level habitat quality rank for the purpose of making relative comparisons among streams within a watershed. The FishEye framework is a system of assigning and combining habitat quality ranks for physical stream variables and habitat preference ranges for multiple species. We designed this model to determine relative rankings for potential salmonid habitat quality independent of documented fish use, which can vary, depending on data quality.

General Approach

We determined the basic biological and physical parameters needed to reflect both intrinsic potential and anthropogenic effects for habitat variables modeled in the Lewis River Case Study Decision Support System (DSS). Hydrologic modeling and GIS methods were used to derive physical stream-based parameters at the stream reach scale (WDFW 2003; Miller 2005). Methods for creating reach-scale estimates of bed scour, hydroregion, fine sediment, scour potential, and riparian habitat are described or referenced in the following sections.

FishEye ranks each stream segment with an estimate of the base intrinsic potential or natural suitability (using the base potential variables) and an anthropogenic rank based on the anthropogenic variables. The natural suitability is differentiated by species, though the anthropogenic rank is not. The final result of FishEye is a series of ratings per species, delineated by the two components, then classified into suitability rankings.

DSS Application

FishEye is used in the LRCS-DSS as a relative measure of fish habitat quality under current, historical, and a variety of restored watershed conditions or scenarios. Final FishEye scores provide a qualitative method of describing habitat quality that is useful across multiple reaches, or at the sub-watershed scale. It is not predictive at the scale of a single reach (due to modeling and preference uncertainties) and is only appropriately applicable over a length of stream >1 kilometer (depending on predominant reach length) or at the scale of a 7th or 8th field watershed. FishEye scores and results should be clustered or grouped by multiple similar reaches or patches of reaches.

Scores are appropriate to use in conjunction with potential fish capacity predictions in the framework of the associated report (detailed in Appendix I), or can be compared to these predictions. Scores are also appropriate to use as measures of general habitat variability and diversity throughout the watershed under current and historical conditions, and under various modeled restoration scenarios. A few of the metrics used in FishEye are similar to those used in Sanderson et al (In Prep.) and Lunetta et al. (1997). The source of the base stream reach data for FishEye was the Washington Department of Fish and Wildlife (WDFW 2003).

Description of Variables and Scores

The natural suitability component is composed of bank full width, stream gradient, and scour potential. The anthropogenic component includes shade, large woody debris, pool forming conifers, fine sediment, and modified scour potential. Each was broken into qualitative categories based on available references for the purpose of designing a weighting and ranking scheme. Classification into ordinal categories was necessary in FishEye to better reflect the nature of the source references. The primary references provide only general habitat range values; we did not have the appropriate empirical data to warrant the development of curves.

Channel Width

Species-specific accessibility and passability information for various salmonids was available for bank full width (Table J-1). Smaller stream channels (< 4 feet) and the higher gradient channels (see next variable) are equally important and both serve as basic limiting factors to fish access, and also function as indicators of general habitat quality. A width score of 0 indicates that this section of stream is unusable, because of severely limited access or low streamflow. This is a limiting factor. The bank full width threshold value is based on an estimate of limits to anadromous fish used by Washington Department of Fish and Wildlife (2000) which, in turn, is based on the definition of stream thresholds for anadromous and non-anadromous fish as defined by Washington Forest Practices Board (WFPB 2000).

Mainstem spawning fish (fall chinook) are limited to channels greater than 10 feet (3 m) (WDFW 2000). A score of 1 indicates less favorable conditions for summer steelhead and chum, based on flow conditions that are typically associated with streams less than 10 feet in width (WDFW 2000; Burnett et al 2003a; Salo 1991). Scores of 2 indicate generally favorable conditions. Scoring of channel width is highly correlated with flows and gradient, so our purpose in including width is to indicating areas with poor potential or that are completely unusable by most adult salmon of the species. Species were assigned only 0's and 2's where source information only indicated two conditions – limited or no access, or width suitable for fish passage. The assessment area for chum in the DSS only includes areas downstream of natural and manmade barriers, so chum results do not include any streams <2 m in width.

Gradient

Gradient indicates species-specific differences in stream accessibility, passability, and physical habitat preference (Table J-1). Boundaries between gradient categories should be considered as general transition zones between suitability, rather than firm threshold breaks in the natural environment. Uncertainty in gradient estimation techniques (both remote and field), scale of reach-level gradient estimates (length of reach), and variation in the size of adult fish, all affect confidence levels in ranking gradient quality for fish. Gradient alone is not an absolute indicator of excellent habitat, obviously, and should be considered in combination with the other variables in FishEye, as well as with multiple environmental variables we are unable to represent in FishEye (fish density, fish behavior, flow, aquatic quality factors, etc.).

Similar to channel width, a 0 indicates complete lack of accessibility or use and is a limiting factor rather than a preference. Information on gradients that are limiting was more consistent between sources than the gradient preference information, and in most cases reflects the upstream natural gradient barrier to fish. Typically, these represent waterfalls or cascades. Longer reach lengths in the GIS stream source can result in an overestimation of gradient rank per reach segment, as the features are not necessarily homogenous within these reaches, but gradient is calculated as an average over the length of the reach (WDFW 2003). Scores 1 - 3 indicate that the stream is useable to the fish, with 3 indicating the most preferred gradient habitat.

Multiple sources were used as references for gradient rankings. Ranges indicated to be indicative of good habitat (3) are positively correlated with fish use and spawning in various reference sources (Steel and Sheer 2003; Cramer, Galovich, Hunt, Hymer, Schroeder and Kenniston, Wade, Ziller – Pers. Comm.; Burnett et al 2003a). Moderate quality gradient habitat (2) was defined using ranges outlined in WDFW (2000) and Burnett et al (2003a). Poor quality or streams indicated to be barely passable (1) are streams with highly variable seasonal access, or are have features that make gradient predictions difficult, or where adjacent habitat indicated high gradient levels (WDFW 2000; Burnett et al 2003a). Cutoffs or limits to accessibility (0) were also obtained from these sources.

Table J-1. Gradient and channel width preference ranges and scores by species. A dash (-) indicates that no information was available, or that data sources did not indicate any preference or information on the particular species or physical characteristic. Column headings indicate species; both score number and score descriptor are provided for each species by gradient level. Score numbers described in the text were converted to descriptors “Good,” “Moderate,” and “Poor” for ease of interpretation. Asterisks (*) indicate that the reference source differed from the other source indicating “moderate” quality habitat for this species (WDFW 2000).

Gradient (%)	Chinook (spring)		Chinook (fall)		Steelhead (winter)		Steelhead (summer)		Steelhead (Burnett 2003)		Chum	
0 - 1	Fair	2	Fair	2	Fair	2	Fair	2	Fair	2	Good	3
1 - 2	Good	3	Good	3	Good	3	Fair	2	Fair	2	Good	3
2 - 3	Fair	2	Fair	2	Good	3	Fair	2	Good	3	Fair	2
3 - 4	Fair	2	Fair	2	Good	3	Good	3	Fair	2	Poor	1
4 - 5	Fair*	2	Fair*	2	Good	3	Fair*	2	Fair	2	Poor	1
5 - 6	Fair*	2	Fair*	2	Fair	2	Fair*	2	Fair	2	-	0
6 - 7	Fair*	2	Fair*	2	Fair*	2	Fair*	2	Fair	2	-	0
7 - 8	Poor	1	Poor	1	Fair*	2	Fair*	2	Fair	2	-	0
8 - 12	Poor	1	Poor	1	Fair*	2	Fair*	2	Poor	1	-	0
12 - 15	Poor	1	Poor	1	Poor	1	Poor	1	Poor	1	-	0
15 - 16	Poor	1	Poor	1	Poor	1	Poor	1	-	0	-	0
16 - 20	-	0	-	0	Poor	1	Poor	1	-	0	-	0
> 20	-	0	-	0	-	0	-	0	-	0	-	0
Channel Width												
< 2m	-	0	-	0	-	0	-	0	-	0	-	0
2-10m	Good	2	-	0	Good	2	Fair	1	Fair	1	Fair	1
> 10m	Good	2	Good	2	Good	2	Good	2	Good	2	Good	2

Hydrologic Scour Potential

Natural variability and hydrologic regimes in rain-dominant versus snow-dominant systems can impact spawning success through differences in bed scour and egg survival (Montgomery et al. 1999). Hydrologic regime variations across a population's range may indicate spatial diversity and life history adaptations (Beechie et al. 2006). Hydroregion is correlated with differences in natural hydrologically-driven scour and reflects the hydrologic landscape independent of land cover. Hydrologically-based factors have implications for spawning quality based on bed scour and relative success of redds (Montgomery et al. 1999).

In FishEye, we used details from a study by Montgomery et al (1999) to determine hydrologic scour scores by fish species (Table J-2). The dominant hydrologic regime influencing the segment and gradient were used to characterize an overall seasonal scour potential for each species. Based on Montgomery et al. (1999), a high gradient was defined as those stream reaches with >3% channel slope, and low gradient as reaches with < 3% channel slope. It is important to note that gradient is a natural suitability variable, so it is incorporated twice in the FishEye model—under general gradient and in scour potential rules. A score of 0 indicates a negative rank for scour, indicating that adult fish of this species (especially the larger fish) have a high risk of experiencing a negative effect (i.e., low productivity) due to egg mortality from scour events. A score of 1 indicates a neutral effect, or no documented negative or positive effect for this condition. A score of 2 indicates that this condition is a generally positive condition for egg survival, though actual conditions are subject to behavior and environmental variability, such as egg burial depth and actual fish size. The positive score would primarily apply to the larger fish in the cohort, which would have a very low risk of a negative scour impact, due to their deeper egg burial depths (Montgomery et al. 1999).

Table J-2. Hydrologic region scour scores based on Montgomery et al (1999). A score of 1 indicates a neutral or undocumented effect. Chum only have two possible scores, since source data only provided information on possible negative impacts.

Precipitation	Other	Rain		Rain-on-Snow	Snow	
Gradient	All	<3%	>=3%	All	<3%	>=3%
Spring Chinook	1	2	2	1	1	-
Fall Chinook	1	1	-	1	2	2
Winter Steelhead	1	2	2	1	1	-
Summer Steelhead	1	2	2	1	1	-
Steelhead (Burnett 2003)	1	2	2	1	1	-
Chum	1	1	-	1	-	-

Dominant upstream hydrologic regime was calculated for individual stream reaches using existing base hydrologic zone spatial data from Washington State Department of Natural Resources (WDNR 1991). This hydrologic data layer was derived from information on locale climate, elevation, average January snowpack, and latitude in the Lewis watershed, as defined by Washington DNR.

Hydroregion was determined for each segment using GRID functions in ArcGIS. A grid was created for each of the five dominant hydrologic/ precipitation classes (highland, snow, rain on snow, rain, or lowland). Hydrologic flow direction was determined from

the 10 m digital elevation model. Upstream connectivity and identification of drainage source was identified for all segments by tracking the source and amount of contributing cells to each stream channel. Weighted and non-weighted flow accumulation grids were generated for each of the five hydrologic landscape categories. These grids were summed together, and the hydrologic landscape source was determined for each pixel by dividing the summed flow accumulation values by the original landscape source code number. The dominant region code flowing into the stream for each segment was assigned to each stream segment using a spatial overlay.

Riparian

Riparian condition scores are determined without species-level differentiation. Available references and the limited precision of riparian vegetation data were not appropriate for determining species-level scores. Riparian condition is used to indicate the general quality of the riparian forest with respect to large woody debris recruitment, pool forming conifers, and shade (Appendix H). All species in the analysis have the same score for these riparian variables. A score of 0 indicates poor habitat, 1 indicates fair or moderate with respect to the parameter, and 2 indicates that the riparian conditions meet the rules designated for good riparian conditions for that feature.

Fine Sediment

Fine sediment is the second anthropogenic variable. Sediment deposition from surface run-off or mass-wasting is a natural occurrence that can be amplified by anthropogenic activities. The fine sediment score is an indicator of deposition in the stream channel. It is based on the difference between the natural sediment deposition for the reach (assuming fully vegetated land cover) and the estimated fine sediment deposition for the current conditions. The variable is designed to measure relative differences in the deposition of fines in stream channels in the Lewis. The amount of fines in a reach was measured as the proportion of all sediments with a grain size < 1 mm that are deposited in a stream reach.

The relationship between egg-to-fry survival and sediment particle size was used to determine the fine sediment ranking categories used in FishEye (Table J-3). Figures 1 and 2 of Appendix K refer to the proportion of sediment within streams from field-collected substrate core samples. The sediment information is available as the overall amount of fines deposited in the reach from both lateral and upstream. Although comparable, these ranks are only appropriate for comparisons between reaches, and do not represent within-reach variability. We use these relationships between fish density and egg-survival for relative ranking (between stream reaches) purposes. Because the sediment particle size thresholds were determined from empirical studies, the translation of sediment particle size thresholds from field-measured sediment to modeled sediment predictions includes some uncertainty.

Similar to other FishEye variables, the sediment scores (Table J-3) are designed to reflect the relative quality of habitat and survival based on published studies. As noted in Appendix K, the original studies are based on dividing the percent of fines by size class, with fines defined as substrate less than 0.85 mm. The sediment modeling procedure was based on general soil horizon distributions, and estimation of the proportions of the soil horizons comprised of substrates with a grain size ≤ 1 mm (described in Appendix A).

Table J-3. Sediment scores were determined from the egg-to-fry survival functional relationships as described in Appendix K. Table includes survival by species, associated percent fines, and FishEye score value. Survival by percent fines was used to determine the rank score for FishEye. The rank score, not the survival rate, was used as the final FishEye score.

Species Survival	Percent fines in reach (<i>proportion of 0 – 1.0mm grain size fine substrate</i>)		
	Good (%fines/reach) Score = 2	Fair (%fines/reach) Score = 1	Poor (%fines/reach) Score = 0
Steelhead	0-10	10-14.6	> 14.6
<i>Egg-to-fry survival</i>	> 64.7	64.7-32.4	< 32.4
Chinook	0-5.9	5.9-13.3	> 13.3
<i>Egg-to-fry survival</i>	> 37.3	37.3-18.6	< 18.6
Coho	0-10.2	10.2-18.5	>18.5
<i>Egg-to-fry survival</i>	> 56.5	56.5-23.8	< 23.8

Modified Scour

The modified scour potential rank is defined as the relative risk of scour based on the 2.3- year flood flow levels. The 2.3-yr flood magnitude is described further in Appendix E. This variable provides information on runoff and discharge as it relates to in-stream scour potential. The scour potential may change if upstream land use is modified extensively enough to affect runoff / discharge for the 2.3-yr flood magnitudes. A scour index was calculated as part of the sediment modeling procedure, converted into percentile ranks, then grouped into categories of relative quality (Table J-4). Modified scour is related to the hydroregion, except that it incorporates runoff and discharge from the hillslopes and does not incorporate physical channel and precipitation conditions. Modified scour scores are determined using results from the dynamic sediment routing procedure (Appendix F). We used the distribution of scour index (I_s) values for Lewis River streams (Appendix F) under historical conditions within the winter steelhead distribution habitat extent, including current and historical habitat to define natural value thresholds (Figure J-1 and Figure J-2). The distribution of scour indices (I_s) is primarily affected by changes in lateral vegetation (riparian habitat) and variation in land cover type and soil type. We used the distribution of historical landscape conditions to determine the natural percentile breaks in the environment for runoff, discharge, and bed scour, in order to assess anthropogenically-driven changes under current or potential conditions.

Base threshold values were set at proportions of 0.5, 0.3, and 0.2 in the distribution (Figure J-1 and Figure J-2; Figure 4 of Appendix F). Bin ranks assigned based on this distribution were too general to allow effective differentiation between scour risk; I_s values were then differentiated by 20th percentile categories. Index values greater than or equal to 0.11 were given a score of 0 (very high risk) indicates a very high probability of potential scour from land use and corresponding negative impact on habitat from scour events. Index values greater than or equal to 0.08 and less than 0.11 have a very high scour effect risk (rank of 1; very high risk), I_s values greater than or equal to 0.06 and less than 0.08 represent a moderate scour effect risk (rank of 2; moderate risk) within the natural distribution. Index values greater than or equal to 0.03 and less than 0.06 have a low potential for land-use scour risk (score = 3; low risk), and values less than this have a very low potential (score = 4; minimal or close to base conditions).

Table J-4. Bed scour potential and percentile ranks by stream length. Based on natural scenario bed scour values (I_s) (base flood discharge) for streams $> 1 \text{ km}^2$ within the extent of the current and historical range for winter steelhead. Percentile ranges are indicated in column headings. FishEye scores apply equally to all species. Distribution of values was used to derive relative ranks. The highest value is the maximum bed scour value (I_s) possible for that segment.

Base Bed Scour (modified)	Base (0-20th)	Low (20-40th)	Moderate (40-60th)	High (60-80th)	Very High (Max)
I_s (baseflood discharge) range	0 - 0.0243	0.0243 - 0.0606	0.0606 - 0.0835	0.0835 - 0.1182	> 0.1182
FishEye Score	4	3	2	1	0

Integration of Variables

Scores from all variable components were combined to provide a rating to reflect the habitat quality for the stream reach. Habitat variables that incorporate the three natural suitability scores were combined to create a unique code that reflects the base intrinsic potential of the reach. Riparian, fine sediment and modified scour scores vary by land use conditions, upslope land cover, and riparian habitat quality. These scores were not incorporated into the natural suitability rating, since they reflect anthropogenic changes in current and restored watershed conditions. A binary combination method was used to allow discernment of unique combinations of variables throughout, and final qualitative, descriptive ratings were determined from these.

Combining Habitat Scores

The natural suitability component incorporates preference differences between species. This means that each species may have a different natural suitability code for the same stream segment. The Results section includes a description of case limitations by species. The multiple values were converted to a single binary score in an equation, by making the multiplier equal to the maximum number of scores within each of the incorporated variables, raised to the power of the number of variables (initiated with a power of 0), minus one for each variable in order. The variable with the most weight occupies the first position in the equation, and the variable in the last position has the least weight, since it is raised to a power of 0.

The binary code for natural suitability was calculated with width as the highest weight, since this variable was primarily a limiting factor rather than a quality indicator. The code was calculated as follows (Eq. 1):

Equation 1

$$W(4^2) + G(4^1) + HS(4^0) = \text{Natural Suitability Code}$$

Where:

W = width score

G = gradient score

HS = hydrologic scour potential score

The description for scores by species can be tracked back to original values in Table J-1 and Table J-2. The natural suitability variable combinations and codes are in Table J-1. These codes were used specifically to allow various conditions to be easily grouped into ratings of good, fair, and poor. Below is an example of the unique binary codes derived from Equation 1:

A BP of "21" =	$1(4^2) + 1(4^1) + 1(4^0)$
A BP of "42" =	$2(4^2) + 2(4^1) + 2(4^0)$
A BP of "58" =	$3(4^2) + 2(4^1) + 2(4^0)$

Riparian condition code was calculated with a similar approach (Table J-1). In this binary code equation, the multiplier is 3 since there is a possibility of a maximum of 3 unique codes among the 3 variables, raised to the power of the number of variables (minus 1) (Eq. 2):

Equation 2

$$S(3^2) + LWD(3^1) + PFC(3^0) = \text{Riparian Condition Code}$$

Where:

S = shade score

LWD = large woody debris score

PFC = pool forming conifer score

Ranks for fine sediment and modified scour were combined into a binary code representing the modified physical function of the stream, or the instream habitat (Table J-1). This code also represents anthropogenically modified habitat. The multiplier is 5 since there is a possibility of a maximum of 5 unique scores from modified scour and fine sediment variables (Eq. 3).

Equation 3

$$MS(5^1) + FS(5^0) = \text{Instream Habitat Code}$$

Where:

MS = modified scour potential score

FS = fine sediment score

Table J-1. Final binary scores for all combinations of natural suitability, riparian conditions, and instream habitat. Scores used for binary code calculation are included. The codes were used to determine qualitative rating interpretations for each variable. The ratings are: P = poor, VP = very poor (modified physical function intermediate rating only), F = Fair, M = marginal / moderate, G = good, VG = very good (modified physical function intermediate rating only), and E = excellent (low or naturally low) (modified physical function final rating only).

Base Potential Variables (BP)					Riparian Function (RF)					Modified Physical Function (MPF)				
Wid.	Grad.	Hydro	Bin. Code	Rtg.	Shade	LWD	PFC	Bin. Code	Rtg.	Scour Pot.	Fine Sed	Bin. Code	Int. Code	Rtg.
0	0	0	0	P	0	0	0	0	P	0	0	0	VPP	P
0	0	1	1	P	0	0	1	1	P	0	1	1	VPM	P
0	0	2	2	P	0	0	2	2	P	0	2	2	VPG	F
0	1	0	4	P	0	1	0	3	P	1	0	5	PP	P
0	1	1	5	P	0	1	1	4	P	1	1	6	PM	F
0	1	2	6	P	0	1	2	5	P	1	2	7	PG	F
0	2	0	8	P	0	2	0	6	P	2	0	10	MP	F
0	2	1	9	P	0	2	1	7	M	2	1	11	MM	M
0	2	2	10	P	0	2	2	8	M	2	2	12	MG	M
0	3	0	12	P	1	0	0	9	M	3	0	15	GP	M
0	3	1	13	M	1	0	1	10	M	3	1	16	GM	G
0	3	2	14	M	1	0	2	11	M	3	2	17	GG	E
1	0	0	16	P	1	1	0	12	M	4	0	20	VGP	M
1	0	1	17	P	1	1	1	13	M	4	1	21	VGM	G
1	0	2	18	P	1	1	2	14	M	4	2	22	VGG	E
1	1	0	20	M	1	2	0	15	M	-	-	-	-	-
1	1	1	21	M	1	2	1	16	G	-	-	-	-	-
1	1	2	22	M	1	2	2	17	G	-	-	-	-	-
1	2	0	24	M	2	0	0	18	M	-	-	-	-	-
1	2	1	25	M	2	0	1	19	G	-	-	-	-	-
1	2	2	26	M	2	0	2	20	G	-	-	-	-	-
1	3	0	28	M	2	1	0	21	M	-	-	-	-	-
1	3	1	29	M	2	1	1	22	G	-	-	-	-	-
1	3	2	30	G	2	1	2	23	G	-	-	-	-	-
2	0	0	32	P	2	2	0	24	G	-	-	-	-	-
2	0	1	33	P	2	2	1	25	G	-	-	-	-	-
2	0	2	34	P	2	2	2	26	G	-	-	-	-	-
2	1	0	36	M	-	-	-	-	-	-	-	-	-	-
2	1	1	37	M	-	-	-	-	-	-	-	-	-	-
2	1	2	38	M	-	-	-	-	-	-	-	-	-	-
2	2	0	40	M	-	-	-	-	-	-	-	-	-	-
2	2	1	41	G	-	-	-	-	-	-	-	-	-	-
2	2	2	42	G	-	-	-	-	-	-	-	-	-	-
2	3	0	44	G	-	-	-	-	-	-	-	-	-	-
2	3	1	45	G	-	-	-	-	-	-	-	-	-	-
2	3	2	46	G	-	-	-	-	-	-	-	-	-	-

FishEye Final Ratings

Results of the FishEye approach are generated at two levels – the individual habitat variable ratings, and the overall observed suitability rankings. The habitat ratings can be used to indicate the source of habitat limiting factors by stream segment – from either natural intrinsic features, or anthropogenic impacts (Table J-1 and Table J-1). The observed suitability ranking is meant to estimate the overall habitat quality (Table J-1).

Habitat-specific Rating Process

The binary codes for natural suitability and the anthropogenic components are designed to provide continuous gradations in variable scores (Table J-1). Since variable thresholds differ by weight, influence, source, and sensitivity, their associated binary codes are distinct from each other. This design provides flexibility and transparency in the ranking process, and allows the discernment of variables per segment reach. Secondly, the combinatorial framework is designed to bin final scores into general qualitative ratings. The ordered binary codes were used to determine more descriptive qualitative ratings, relative to the distribution of conditions in the Lewis River. Individual cases were reviewed and the qualitative ratings in Table J-1 were adjusted where necessary.

Natural suitability, instream habitat, and riparian condition ratings were reviewed by project personnel for accuracy, and adjustments were made based on this process. We determined certain rules to the assignment of qualitative ratings for consistency. Width is a limiting factor, so a 0 for width means the habitat can never be considered good, and are generally considered to be poor habitat. The limiting factor for natural suitability where width is greater than 0 is dependent on stream gradient. Gradient is the second limiting factor, so a 0 here automatically means the habitat is either moderate or poor. A score of 0 for both gradient and width means that it is highly likely the habitat is not accessible to fish, so the stream segment habitat is identified as poor. Of the three natural suitability variables, hydrologic scour potential has the least influence on the binary score weight, since this is dependent on the quality of gradient and width. The highest quality score is 2, which represents the lowest risk for fish. Where hydrologic scour has a positive rank (2), the habitat rating is at least moderate or good unless there is a 0 gradient or width. Since there are only two possible hydrologic scour potential scores for chum, there were a number of score combinations possible for other species that were not possible for chum. The moderate physical function codes and ratings differ in order (see Table J-1), as modified scour and fine sediment are strongly correlated and have a similar impact on physical habitat quality.

Table J-1. Example of FishEye habitat ratings. Summarized habitat descriptors and limiting factors for three stream segments.

Segment ID	Natural Suitability	Riparian Condition	Modified Physical Function	Habitat Quality Limited by?
331	M	G	P	Sediment
332	G	P	G	Riparian
333	M	G	P	Sediment and BP

FishEye Observed Suitability

The final FishEye Observed Suitability rankings were assigned using a matrix of anthropogenic variable(s) and natural suitability potential (Table J-1). The final FishEye ranks provide a generalized qualitative measure of the natural intrinsic suitability in relation to the anthropogenic features (riparian condition and sediment). Spatial distributions of ranks are useful for indicating stream regions with extremes of either type of limiting factor. The categorical nature of the thresholds and ranking scheme used in FishEye means that extremes (good or poor) have a higher source certainty of habitat quality than moderate or fair descriptors.

The ranking process for FishEye variables incorporates this data effect, as streams with a mid-level rank are considered to have a more neutral habitat influence. If the natural suitability is poor, the best the overall rank can be is moderate, and can only be moderate if the other two variables (modified physical process and riparian) are good or excellent. If natural suitability is fair, the overall FishEye ranking can be good, but only if both riparian and physical process conditions are at least good. Where natural suitability is good, the overall rank is good if just one of the other two variables is also good.

Table J-1. Observed suitability rankings as a function of natural suitability, riparian condition, and physical process condition. Code indicates the final quality rank assigned to the stream segment. P = Poor Quality, F= Fair Quality, A = Adequate/Moderate Quality, and G = Good Quality.

Natural Suitability		Modified Physical Function				
		Poor	Fair	Moderate	Good	Excellent
Riparian Condition	Natural Suitability = Poor					
	Poor	P	P	P	F	F
	Moderate	P	P	F	F	F
	Good	P	F	F	A	A
	Natural Suitability = Fair					
	Poor	P	F	F	F	F
	Moderate	P	F	F	A	A
	Good	F	F	A	G	G
	Natural Suitability = Good					
	Poor	F	F	F	F	G
	Moderate	F	A	A	G	G
	Good	F	A	G	G	G

Results

Intermediate results from each FishEye component and final FishEye suitability ratings for multiple species are included in Figure J-1 through Figure J-8.

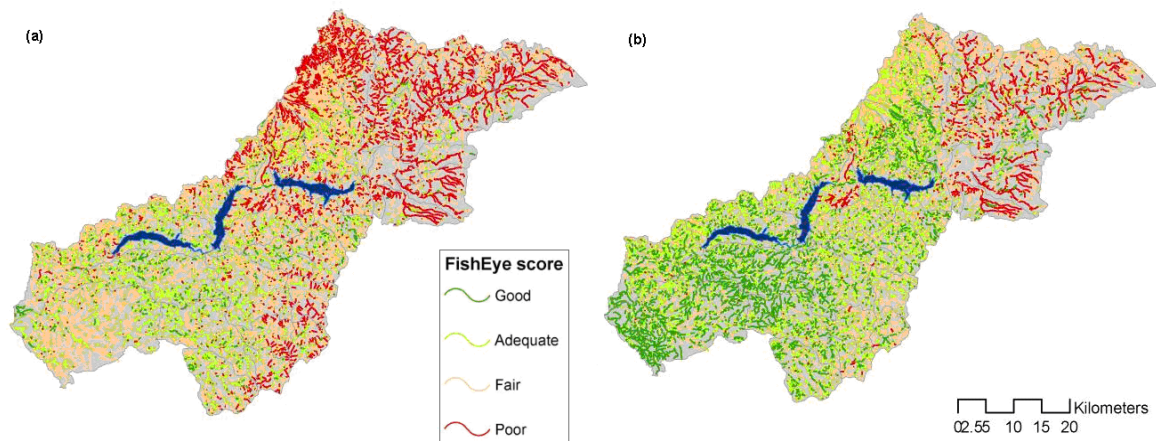


Figure J-1. FishEye Observed suitability rankings for current conditions (a) and pre-development conditions (b) for spring chinook salmon.

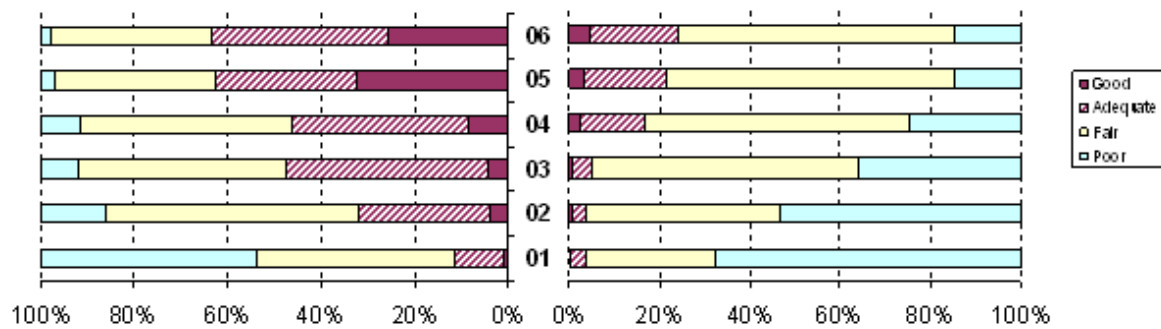


Figure J-2. FishEye Observed suitability rankings by percent for spring chinook for historical (left) and current (right) conditions. Results are grouped by the abbreviated 5th field hydrologic unit code on the y-axis.

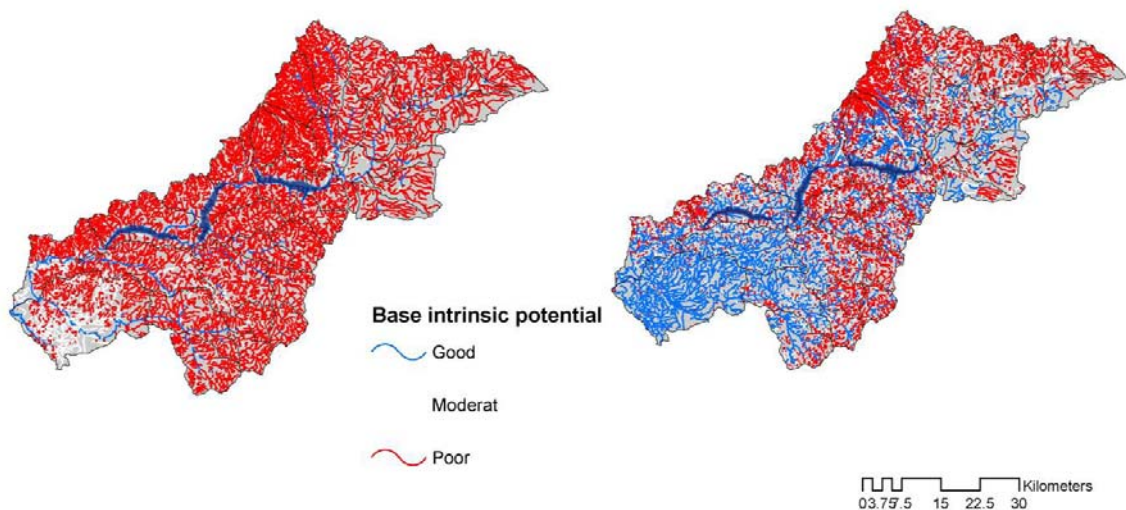


Figure J-3. Natural suitability, or base intrinsic potential for (a) chum salmon and (b) winter steelhead for all streams in the watershed. This includes areas upstream of natural and manmade barriers. A “moderate” potential is represented by white streams, though not clearly distinguished in the legend.

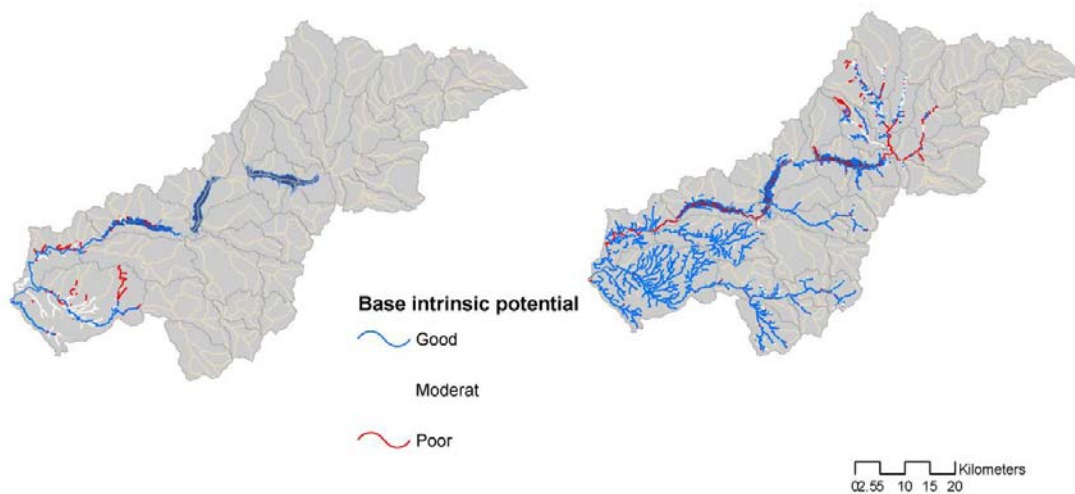


Figure J-4. Natural suitability, or base intrinsic potential for (a) chum salmon and (b) winter steelhead including only historical (pre-dam) distribution areas. The base intrinsic potential includes physical parameters only, so indicates the natural topographic limits to fish distribution and potential habitat. See Appendix A for a description of how fish distribution was determined. A “moderate” potential is represented by white streams, though not clearly distinguished in the legend.

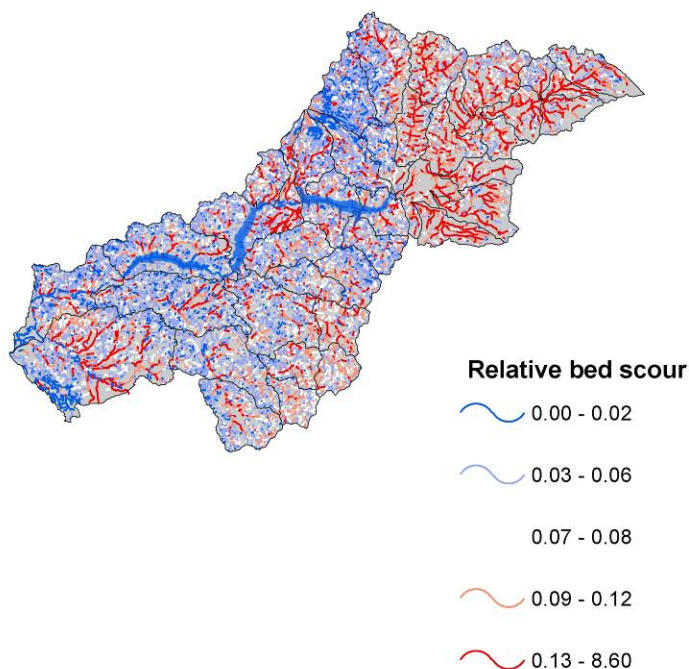


Figure J-5. Modified scour conditions for current conditions. Values > 0.08 are considered to be very high. See Table J-4 for details.

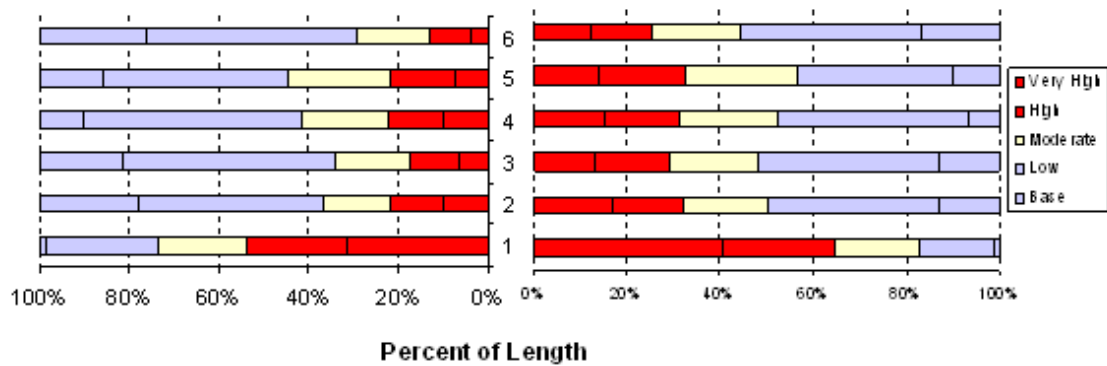


Figure J-6. Difference in high modified bed scour condition rankings for historical (left) and current (right) landscape conditions. Abbreviated hydrologic unit numbers are on the y-axis. More intensive bed scour is indicated by either “high” or “very high” categories (in purple). This is the second parameter in the modified physical function score in FishEye.

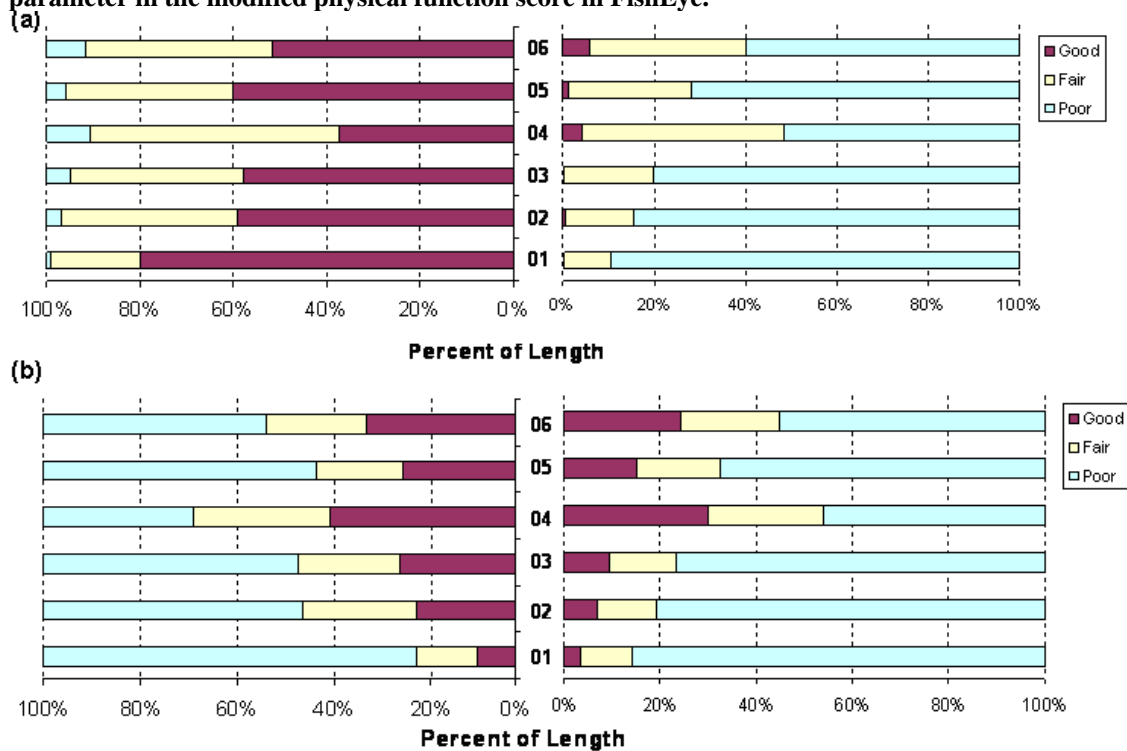


Figure J-7. Percent fines results for (a) juvenile steelhead and (b) juvenile chinook salmon for historical (left) and current (right) templates. Abbreviated hydrologic unit numbers are on the y-axis. See Table J-3 for more information. Percent fines were incorporated into the modified physical function component of FishEye.

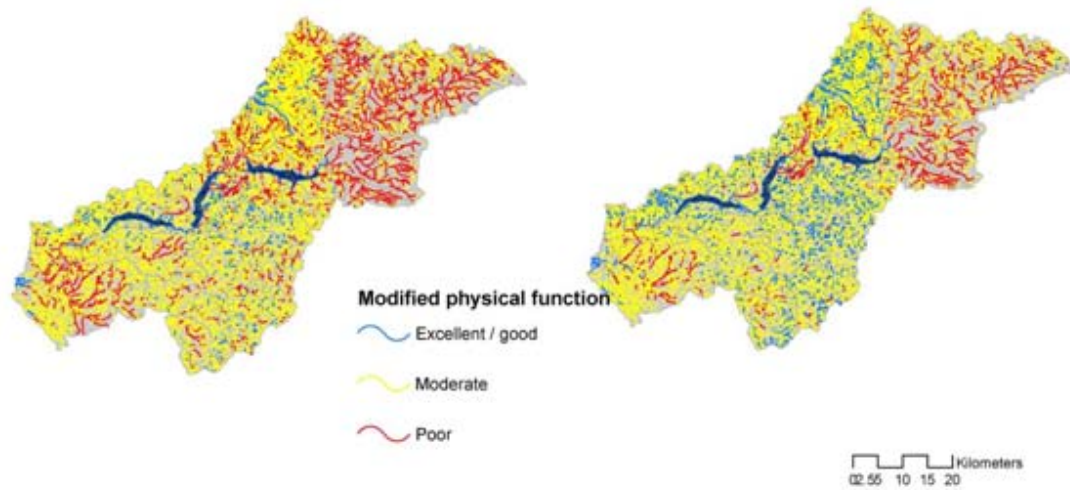


Figure J-8. Modified physical function ratings for FishEye for (a) current conditions and (b) historical conditions. Modified physical function includes modified bed scour and fine sediment.

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